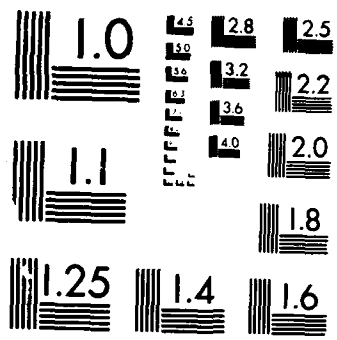
AD-A171 949 LASER PHYSICS AND LASER TECHNIQUES(U) STANFORD UNIV CA EDWARD L GINZTON LAB OF PHYSICS A E SIEGMAN 19 MAY 86 AFOSR-TR-86-0723 F49620-84-C-0041 1/1

UNCLASSIFIED F/G 14/2 NL



MICROCOPY RESOLUTION TEST

NATIONAL BUREAU OF STANDARDS

AFOSR-TR- 86-0723

(2)

AD-A171 949

LASER PHYSICS AND LASER TECHNIQUES

Approved for public release; distrib^ution unlimited.

Final Technical Report

to

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

under Contract No. F49620-84-C-0041

for the period

1 March 1984—28 February 1986

Principal Investigator

A. E. Siegman

Professor of Electrical Engineering

Edward L. Ginzton Laboratory

Stanford University

Stanford, California 94305

May, 1986

FINAL TECHNICAL REPORT
AFOSR Contract F49620–84–C–0041

A. INTRODUCTION

The general objectives of this program have been to develop new technologies for exploiting the ultrafast measurement and data transmission capabilities of lasers, and especially ultrashort laser pulses, and to apply these new capabilities to significant current scientific problems in physics, chemistry, and ultrafast electronics. Accomplishments that have been made under this contract support in different areas of this program are outlined below.

B. SEMICONDUCTOR LIFETIME AND SURFACE DAMAGE MECHANISMS

During this contract we extended and completed the program of work done in our group by Dr. Philippe Fauchet, first as a student and then as an IBM postdoctoral fellow, on picosecond measurements of semiconductor lifetimes and laser surface damage (see references 1 to 3 below). Dr. Fauchet has now become an Assistant Professor of Electrical Engineering at Princeton.

During the course of this work we observed, more or less accidentally, and were led to study further the very interesting spontaneous surface ripples that can be generated on almost any surface by a *single laser beam*, even in a single picosecond laser shot. Because of their similarity in many basic respects to the well-known Wood's anomalies in diffraction gratings, we now refer to these spontaneously occurring ripples as "Stimulated Wood's Anomalies." Because they can be formed on almost any surface, using almost any laser beam, and because they can change drastically the absorption properties of the surface, an understanding of these spontaneous ripples is important both for surface physics measurements and for surface and target damage studies. We have summarized the properties of these ripples in an invited review paper which will be appearing very shortly (cf. reference 4 below).

1. P.M. Fauchet and A.E. Siegman, "Picosecond dynamics of hot dense electron-hole plasmas in crystalline and amorphized Si and GaAs," in **Ultrafast Phenomena IV,** ed. by D.H. Auston and K.B. Eisenthal, pp. 129–132 (June 11–15, 1984).
2. P.M. Fauchet and A.E. Siegman, "Laser-induced surface ripples: what is understood and what is not," in **Proceedings of MRS Symposium A** (November 1984).
3. P.M. Fauchet and A.E. Siegman, "Surface damage mechanisms in non-transparent media," in **Proceedings of the 16th Symposium on Optical Materials for High Power Lasers** (Boulder, Colorado, October 1984).

4. A.E. Siegman and P.M. Fauchet, "Stimulated Wood's anomalies on laser-illuminated surfaces (invited paper)," *IEEE J. Quantum Electron.* **QE-22,** *to be published* (August 1986).

C. TIME-RESOLVED LUMINESCENCE IN QUANTUM WELL STRUCTURES

Quantum well structures have become extremely important for their applications to both ultrafast optical and electronic devices; and careful measurements of the basic properties of these structures are therefore of both scientific and technical importance. Under this contract Dr. Julie Fouquet carried out a series of ultrafast measurements of the lifetimes of the basic quantum-well transitions in both MBE and MOCVD-grown quantum well structures, using a mode-locked laser and time-resolved single photon counting, as reported in references 5 to 9 below, and in her Ph.D. dissertation (reference 10). Dr. Fouquet is now continuing essentially this same work at the Hewlett-Packard Research Laboratories in Palo Alto.

5. J.E. Fouquet and A.E. Siegman, "Room temperature photoluminescence times in a GaAs-$Al_xGa_{1-x}As$ multiple quantum well structures," in **Proceedings of the 17th International Conference on the Physics of Semiconductors** (Springer-Verlag, August 1984).
6. J.E. Fouquet and A.E. Siegman, "Room temperature photoluminescence times in a GaAs-$Al_xGa_{1-x}As$ molecular beam epitaxy multiple quantum well structure," *Appl. Phys. Lett.* **46,** 280-282 (1 February 1985).
7. J.E. Fouquet, A.E. Siegman, R.D. Burnham, and T.L. Paoli, "Carrier trapping in room temperature time-resolved photoluminescence of a GaAs-$Al_xGa_{1-x}As$ multiple quantum well structure grown by metalorganic chemical vapor deposition," *Appl. Phys. Lett.* **46,** 374-376 (15 February 1985).
8. J.E. Fouquet, A.E. Siegman, R.D. Burnham, and T.L. Paoli, "Time-Resolved Photoluminescence of GaAs-$Al_xGa_{1-x}As$ Quantum Well Structures Grown by Metal-Organic Chemical Vapor Deposition," in **Picosecond Electronics and Optoelectronics** (ed. by G. A. Mourou, D. M. Bloom, and Chi-H. Lee) 143-147 (Springer-Verlag, March 1985).
9. J.E. Fouquet and R.D. Burnham, "Recombination dynamics in GaAs-$Al_xGa_{1-x}As$ quantum well structures," *IEEE J. Quantum Electron.* **QE-22,** accepted for publication (1986).
10. Julie E. Fouquet, "Recombination Dynamics in Quantum Well Semiconductor Structures," Ph.D. Disseratation, Department of Applied Physics, Stanford University (December 1985). (Also GL Report No. 3965, AFOSR Contract F49620-84-C-0041.)

D. TUNABLE TRANSIENT GRATING MEASURMENTS

One of our major objectives over the past several years has been the development of a novel tunable laser-induced grating spectroscopy system for making ultrafast physical measurements in the frequency domain, without the need for ultrashort optical pulses. During the period of this contract this system has been completed and put into operation, and measurements have been made on several chemical systems, notably on the femtosecond time response of the optical Kerr effect in the standard optical Kerr material CS_2. These latter measurements have partially confirmed earlier measurements, and partially demonstrated new and unexpected phenomena which we are still interpreting. Some of the results obtained with this system are reported in references 11 through 13 below, as well as in a lengthy invited review paper in a Special Issue on Laser-Induced Gratings of the IEEE Journal of Quantum Electronics (reference 14).

11. Rick Trebino, C.E. Barker, and A.E. Siegman, "Frequency-domain nonlinear-optical measurement of femtosecond relaxation," in **Laser Spectroscopy VII,** ed. by T. Hänsch and Y. Shen, Springer-Verlag (1985).
12. Rick Trebino and A.E. Siegman, "Frequency bandwidths in nondegenerate N-wave-mixing interactions and induced-grating geometries," *Opt. Commun.*, accepted for publication (1986).
13. Rick Trebino, Eric K. Gustafson, and A.E. Siegman, "Fourth-order partial-coherence effects in the formation of integrated-intensity gratings with pulsed light sources," *JOSA B: Opt. Phys.* **3,** accepted for publication (1986).
14. Rick Trebino, Charles E. Barker, and A.E. Siegman, "Tunable-laser-induced gratings for the measurement of ultrafast phenomena (invited)," *IEEE J. Quantum Electron.* **QE–22,** to be published (1986).

E. DYE LASER AND OPTICAL RESONATOR DESIGN RESULTS

As side developments from our efforts on picosecond measurement techniques and measurements, we have derived and published two analyses having to do with the optimum design of prism beam expanders for pulsed dye lasers, and also two analyses having to do with aspects of laser resonator design, namely:

15. Rick Trebino, "Achromatic N-prism beam expander: Optimal configurations," *Appl. Opt.* **24,** 1130–1138 (15 April 1985).
16. Rick Trebino, Charles E. Barker, and A.E. Siegman, "Achromatic N-prism beam expanders: Optimal configurations II," in **SPIE Proceedings: Southwest Conference on Optics** .
17. A.E. Siegman, "ABCD matrix elements for a curved diffraction grating," *J. Opt. Soc. Am. A* **2,** 1793 (October 1985).
18. A.E. Siegman, "Design considerations for laser cavities using variable reflectivity mirrors," *IEEE J. Quantum Electron.* **QE–22,** accepted for publication (1986).

F. GENERAL REVIEWS

Finally, two invited review papers were prepared and presented, one a review of picosecond spectroscopy techniques for a NATO Conference on Chemical Applications of Picosecond Pulses, and one a general overview of lasers for an anniversary symposium held by the National Academy of Engineering:

19. A.E. Siegman, "Alternative techniques for picosecond spectroscopy," invited review for **Applications of Picosecond Spectroscopy to Chemistry,** ed. by K. B. Eisenthal, Reidel Publishing Co., NATO ISA Series, pp. 325-351 (1984).
20. A.E. Siegman, "The Laser—Still Young After Twenty Five Years?," invited review for **Laser Applications: A Symposium,** National Academy of Engineering, Washington, DC, November 1985 (to be published).

G. ADVANCED DEGREES AND OTHER ACTIVITIES

During this period Dr. Julie Fouquet received the Ph.D. degree in Applied Physics, with a Ph.D. dissertation listed as reference 10 above.

The principal investigator Professor A.E. Siegman received a Senior Scientist Award from the Alexander von Humboldt Foundation and spent a portion of the period 1984–1985 in research at the Max Planck Institute for Quantum Electronics in Germany (at no direct cost to the contract). He was also selected as co-chairman of the next OSA Topical Meeting on Ultrafast Phenomena, which will be held in Colorado in June 1986.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A171 949

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 86-0723
6a. NAME OF PERFORMING ORGANIZATION Stanford University 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Air Force Office of Scientific Research
6c. ADDRESS (City, State and ZIP Code) Edward L. Ginzton Laboratory Stanford, California 94305	7b. ADDRESS (City, State and ZIP Code) Directorate of Physical and Geophysical Sciences Bolling AFB, DC 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR 8b. OFFICE SYMBOL (If applicable) NP	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract F49620-84-C-0041
8c. ADDRESS (City, State and ZIP Code) AFOSR/NP Bldg. 410 BAFB DC 20332-6448	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: 61102F PROJECT NO.: 2301 TASK NO.: A1 WORK UNIT NO.:
11. TITLE (Include Security Classification) Laser Physics & Laser Techniques (unclassified)	
12. PERSONAL AUTHOR(S) A. E. Siegman	
13a. TYPE OF REPORT Final Tech. Report 13b. TIME COVERED FROM 3/1/84 TO 2/28/86	14. DATE OF REPORT (Yr., Mo., Day) 1986 May 19 15. PAGE COUNT 5
16. SUPPLEMENTARY NOTATION	
17. COSATI CODES FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) lasers, femtosecond pulses picosecond pulses

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The objective of this program ~~has been to~~ develop new technologies for exploiting the ultrafast data transmission and measurement capabilities of lasers and ~~to~~ apply these new techniques to current scientific problems in physics, chemistry, and ultrafast electronics. ~~Under this support we have~~ developed several new techniques for making ultrafast measurements with lasers, both using ultrashort light pulses in combination with novel detection mechanisms to make ultrafast measurements in the time domain, and also using a novel "tunable-laser-induced grating method" for making ultrafast measurements without pulses, working in the frequency domain. Using the latter approach, we have made femtosecond resolution frequency-domain lifetime measurements on chemical systems, including the important optical Kerr material CS_2. ~~We have also demonstrated~~ the first picosecond-pulse time-domain measurements using photoacoustic detection as a sensitive and flexible bulk and surface detection mechanism in liquids and solids. ~~We are now working~~ to ~~extend~~ this approach to use photothermal detection as a sensitive

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL A. E. Siegman	22b. TELEPHONE NUMBER (Include Area Code) (415)723-0222 22c. OFFICE SYMBOL Professor

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

flexible, noncontacting method for making picosecond and femtosecond measurements on a very wide variety of surfaces. ~~We have also~~ made a number of lifetime and damage studies on semiconductor surfaces, and ~~explored~~ the formation of spontaneous surface ripples or "stimulated Wood's anomalies" using picosecond laser pulses.

In addition, we have invented an entirely new ultrafast photodetector concept, based on ultrafast diffusion-driven charge transport, ~~and are actively pursuing~~ its experimental demonstration at the minute.

END
DTIC
11-86